Methods for Providing Indications of Robot Intent in Collaborative Human-Robot Tasks

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ABSTRACT

Human-robot collaboration is becoming more common in factories. In this paper, we present our designs for methods for providing information to a person about the robot's intent before the robot moves into the shared work space. We discuss our plan for a human-subjects study to determine which methods are best to express the robot's intent in an easily understandable way. Our study is also designed to determine the optimal distance from the work space to show signals of intent on the robot itself. The goal of our work is to improve efficiency and safety in human-robot collaboration.

CCS CONCEPTS

• **Human-centered computing → HCI design and evaluation methods**; • **Computer systems organization →** *Robotic autonomy*;

KEYWORDS

Robot intent; feedback methods

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1 INTRODUCTION

Workers often have to collaborate, in close proximity, with robots in a factory setting. It is necessary for these workers to know how the robot is planning to move in order to produce a safe and efficient work environment. The robot must be able to clearly show its intent in a way that the workers would notice and understand.

A robot's intent can be expressed through motion or other visual cues; while intent can also be conveyed using audio cues, we have avoided this method given that factories can have significant ambient noise. We hypothesize that intent shown through motion cues will be more recognizable but less comfortable than visual cues that do not involve robot motion (H1). We also hypothesize that cues closer to the work space will be more noticeable than those that are farther away (H2). Additionally, we hypothesize that more legible signals will allow the human's task to be completed faster (H3).

By identifying the signals of robotic intent that humans best understand and the optimal distance from the work space to show signals of intent, we hope to improve the safety and efficiency of human-robot collaboration. In this paper, we describe the cues that we have designed for a Rethink Robotics Baxter humanoid robot and our plans for conducting a human-subjects study.

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2 RELATED WORK

A variety of ways to improve safety in human-robot collaboration have been studied in the past. One method is to use algorithms to improve a robot's awareness of and reaction to human intent [2]. Another way to improve safety is to use anticipatory motion, i.e. motion that conveys what the robot will do, to express intent signals [1]. Generalizing the robot's intent, expressed through visual cues as opposed to signaling every movement that is required to complete its task, has also been found to improve safety in human-robot collaboration [4]. Previous studies have concluded that signals are easier to interpret when they are expressed closer to the work space [1]. Studies involving two people interacting to accomplish a task have also been conducted in order to determine a baseline of how people would attempt to complete a task [3].

3 SYSTEM DESIGN

We have developed multiple cues that allow the robot to express its intent to a person working in the same space, shown in Figure 1.

The first cuing category conveys intent using motion signals, at three varying distances from the work space. The farthest has the robot move its head towards an arm, as if looking at the arm that it intends to move (Fig 1d). The mid-distance signal twitches the elbow of the arm that will move (Fig 1e), modelled after the anticipatory motion found effective for expressing robotic intent in a prior study [1]. The closest motion cue that we have designed is opening and closing the grippers on the arm that will move (Fig 1f).

The second signalling method uses visual cues that do not involve robot motion, also at varying distances from the work space. The farthest visual cue is shown by lighting up either the left or right half of the "sonar" lights to signal which arm the robot will move (Fig 1c). For the mid-distance signal, inspired by the gaze signal found to have effectively conveyed a flying robot's intent [4], the screen on the robot's head will display faces that gaze towards an arm to signal which arm will move (Fig 1a). For the closest visual signal, "navigator" lights on the robot's arms will light up to signal which arm the robot is about to move (Fig 1b).

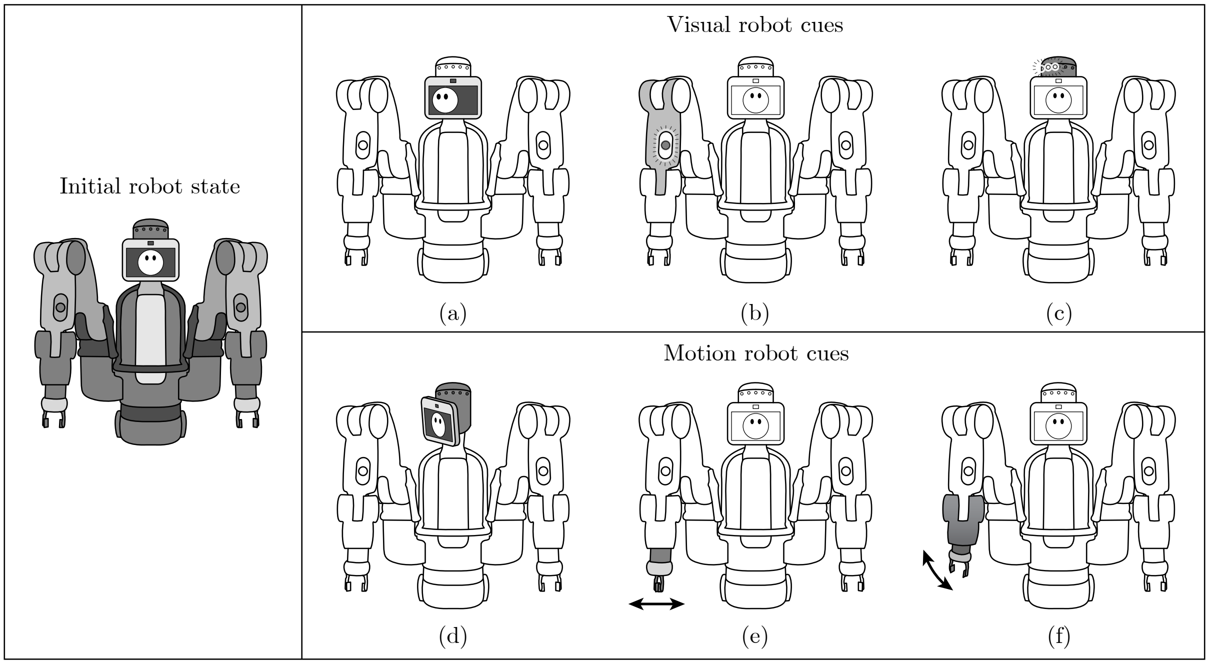

Figure 1: Initial robot state (left) and cues to be performed by the robot (right): (a) gaze, (b) arm lights, (c) head lights, (d) head turning, (e) gripper moving, (f) lower arm movement. Line drawings are used instead of robot images to highlight the different cues. Each image shows the robot giving a cue on its right side; only the portions of the robot being activated are shaded.

4 PLANNED STUDY

Inspired by a previous study [3], we have designed a human-subjects study in which participants will collaborate with a Rethink Robotics Baxter humanoid robot using the intent cues described in the prior section. The task on which they will collaborate has been designed so that turn taking is not required in order to encourage participants to work closely with the robot in a shared work space. The task set up consists of four different squares in a row, each with a unique color. Objects of the same four colors will be placed on the work space. Initially, each object will be placed on one of the three squares that are a different color than the object. The human-subject and the robot will each be responsible for moving objects of two different colors to their appropriate squares. By assigning the robot and the human-subject two colors to sort and by spreading the colored objects across the other squares, we are trying to create a shared work space that would encourage the human-subject to work in close proximity to the robot.

We are planning a between-subjects study, where each participant will have a training period followed by a single interaction with the robot. The conditions will be each of the six intent cues, a baseline condition with no intent communication, and a condition with mixed cues. Using only a single interaction is necessary because participants will be asked after the task is completed if the robot had done anything to let them know how it was planning to move. Once we have asked this question after a run, participants would be primed to look for such signals in future interactions.

We will identify the signals of robotic intent that people best understand by analyzing the survey responses. These responses will also be analyzed to determine the relationship between distance of the signal from the work space and the human-subject's ability to notice the signal of intent. We will measure the human-subject's level of comfort based on how close they get to the robot's arms during the collaborative task. We will also compare the time taken to complete the task by participants who were shown signals of intent against participants who had no intent cues given. By comparing the results from each of the cuing styles, we will also determine how legible each signal of intent is based on how quickly the participant reacts to the signal. Through the results of this study we hope to improve the safety and efficiency of human-robot collaboration.

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